Abstract:
NASA Glenn Research Center, in cooperation with NASA Ames and geologists from the University of Cincinnati and Bowling Green State University, has extended the computational capabilities of the Information Power Grid to remote research sites. The combination of satellite (EOS) data acquisition and the IPG processing provides geologists with the ability to identify the key mineralogical features at the research site. The underlying connectivity for this research environment is provided by the Numerical Research and Education Network (NREN) using a combination of terrestrial and mobile satellite-based networking solutions. Our approach not only speeds the process of scientific discovery, but also serves as a simple demonstration of NASA's capacity for geological classification and exploration of remotes sites such as the Martian surface.

The NASA Glenn Demonstrations combines satellite (EOS) data acquisition and the computational capabilities or the Information Power Grid (IPG) to provide geologists with the ability to identify key mineralogical features in near real-time of an area in study. This capability could someday allow geological classification of rocks and minerals of remotes sites such as the Martian surface.

Extending Grid Computing to Remote Locations

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Experiment Summary

- Real-time Hyperion satellite imagery (data) is sent to an Information Power Grid (IPG) Mass Storage Facility.
- IPG computational facilities extract and process Hyperion satellite data to create a suite of separate band data files.
- Perform up to 64 simultaneous band-ratio conversions on the band data products.
- Data products are then made available in a number of different formats to field researchers.
- The Band-Ratios are used by the remote science team to locate and explore sites of mineralogical importance.

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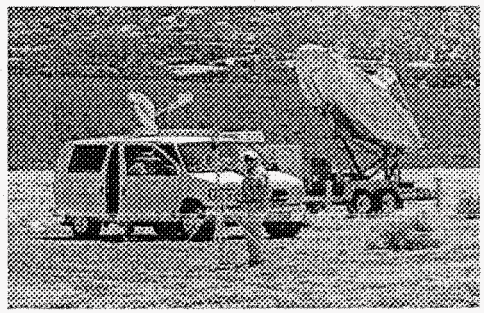
Experimental Setting

- A Research Site near Vernal, UT was chosen for the NASA Ground-Truthing experiment.
  - -Geographically Remote (i.e. isolated from networks).
  - -GPS coordinates for the experiment site were:
    - Latitude: North 40.483°
    - Longitude: West 109.371°
- Experiment Dates: June 23rd–27th, 2003.



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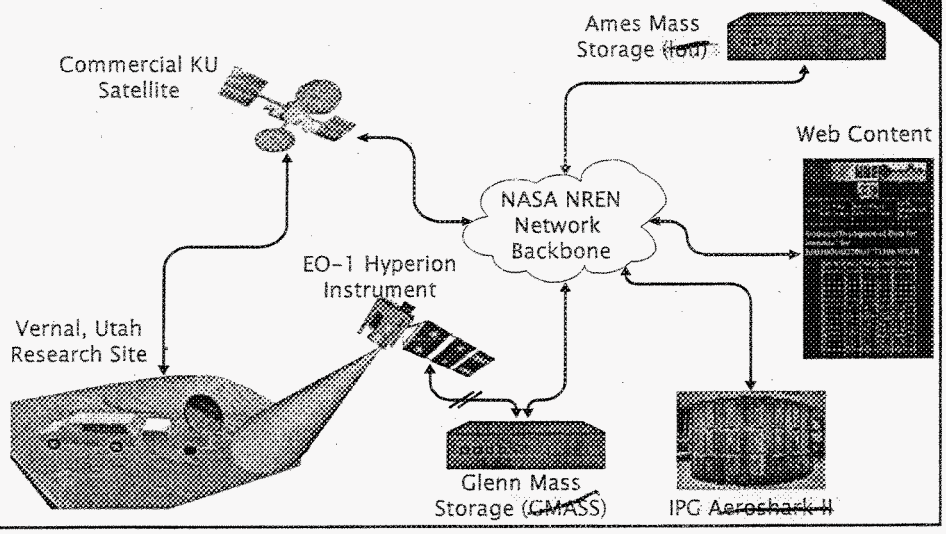
Experiment Resource Architecture



Data Description

- Several Sources of Data were used for this experiment:
  - ADSI FieldSpec Pro Spectral Radiometer – Ground-based Spectroradiometer.
    - Handheld Unit
    - The FieldSpec Pro operates in a spectral range of 350-2500 nm
    - The FieldSpec Pro produces output spectral data files that use the ASD File Format.
    - Stored on Lotus
  - NASA EO-1 Hyperion Hyperspectral Radiometer.
    - The Hyperion instrument on NASA EO-1
    - 220 unique spectral channels from 357 – 2576 nm.
    - 30 meters per pixel resolution,
    - Swath width of 7.5 kilometers.
    - Level 1 Radiometric data product produced by NASA EROS Data Center was used for this experiment.
    - Date Received as Hierarchical Data Format (HDF) file containing Band-Interleaved by Line (BIL) Spectral Data.
    - Processed on Aeroshark II and Stored on GMASS.

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Overview of Data Processing at GRC

- Characterization of Satellite data set
- Validation and Parsing of Satellite band data
- Filter Band Data using:
  - Dark Object Subtraction algorithm
    - A simple, empirical means of calibrating band data.
  - Radiance correction
    - Produces Radiance (W/M^2/steradian) values as opposed to Raw Digital Numbers (DN's).
  - Production of Natural and False Infrared Images
- Creation of Statistical Summary for each band's data
- Submission of Globus Job for simultaneous (concurrent) band-pair ratio calculations to IPG/Aeroshark-II
  - Perform Band-pair validation and ratio calculation
  - Create Band ratio image suite
  - Create Web pages with ratio information
- Update web pages to indicate to field researchers that new data was available for download and analysis.
- Commit new Hyperion data and data products to GMASS.

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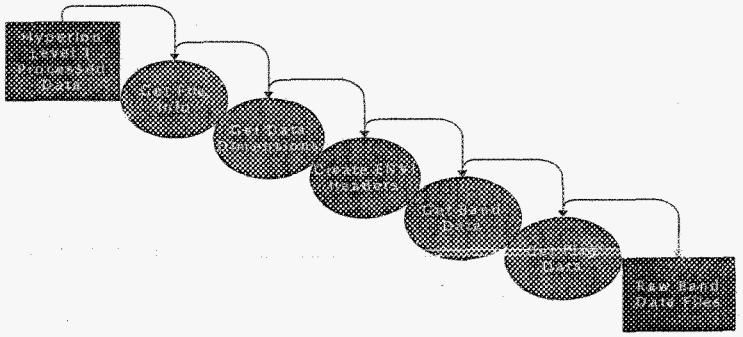
Data Extraction

- Object: Create individual files containing scene data for a single band (wavelength).
  - This is accomplished using:
    - HDP for HDF4.1r5 (NCSA)
    - Custom C++ Parsers – makebands, makeflags



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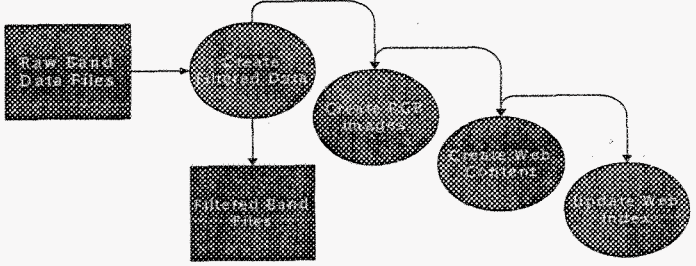
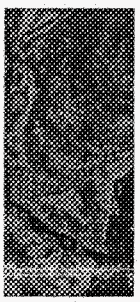
Data Treatment and Content Creation

- Object: Begin creating data products for distribution to field researchers from band data files.
  - This is accomplished using:
    - Custom C++ Filters that perform Dark Object Subtraction and Radiance Corrections
    - Scripts that Create ENVI Header Files
    - Custom C++ Imaging Software



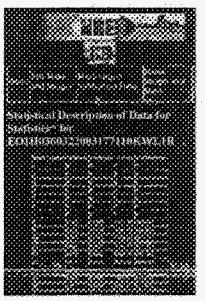
Preliminary Content

- Resulting images and statistical data are published to the web



Natural Color

False Infrared



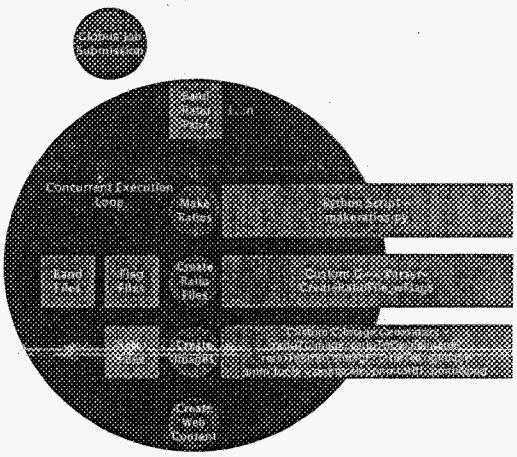
Statistical Summary

Band-Ratio Processing

- Object: Create Band-Ratios for Mineralogical Studies
  - This is accomplished using:
    - Globus Job Submission
    - Custom Python Execution Scripts
    - Custom C/C++ Parsers and Image Generators

Globus Job Submission

- GlobusRatioMaster.py is the controlling script for concurrent processing of up to 64 different band-ratios



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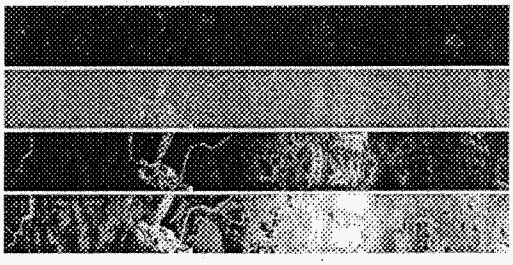
Band-Ratio Content

- Execution of the Globus Job produces multiple TIFF image and binary data files for use by field scientists.



Natural Ratio Band 25/17

Logarithm Ratio Band 25/17

99% Stretch Ratio Band 25/17

Decile Ratio Band 25/17

Processing Time

- The data processing detailed above took relatively little time.
  - The time for the overall processing was 1387.67 seconds (23 min 8 sec).
  - The IPG Job Submission for processing the 37 different band-pair ratios required only 212 seconds (3 min 32 sec).
- Improvements were made during the development of this system.
  - The time required to parse the data from the HDF files was reduced by a factor of 60 during the development cycle of the custom C++ data parsers (i.e., *makebands* and *makeflags*).
  - The time required to complete the submission of jobs to IPG compute resources was reduced by a factor of 10 by transitioning from serial to threaded job submissions.

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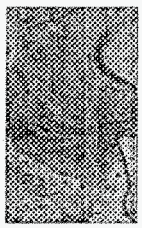
Band-Ratio Requests

- A simple web interface provides researchers with the ability to request additional band-ratio processing products.
- Additionally, Composite RGB images produced from 3 different band-ratios can be requested.
  - These may be used as indicators of the mineralogical composition of the field site.


Hematite


Cuprite


Dakotas Sandstone

Conclusions and Future Directions

- NASA has extended the reach of powerful computing grids to remote locations on Earth.
- The process can be useful for Earth science applications, and can be extended for human missions in space and to other planetary destinations.
- In the future, this computational framework can be usefully extended to provide:
  - 1st Order Mineralogical Characterizations.
  - Better Atmospheric Corrections (i.e. ModTran4)
  - Geographic Subsetting.
  - Geographic Rectification.
  - Integration with Data Sources from the remote research site.

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People

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- University of Cincinnati: Dr. Richard Beck (Principle Investigator.)
- Bowling Green State University: Dr. Robert Vincent (Assistant to PI.)